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Canopy Penetration in Almond Orchards

Part 3: Biological Response Within The Canopy

FHTET 96-04
February 1996

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NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S Environmental Protection Agency, consult your local forest pathologist, county agriculture agent, or State extension specialist to be sure the intended use is still registered.

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CANOPY PENETRATION IN ALMOND ORCHARDS

PART 3:

BIOLOGICAL RESPONSE WITHIN THE CANOPY

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John W. Barry
Project Officer

Foreword

The USDA Forest Service (Forest Pest Management staff) and its cooperators, conducted studies in an almond orchard at the Hennigan almond orchard, Chico, California, during 1985 and 1994. The purpose of the studies was to characterize the penetration and deposition of aerial sprays into deciduous tree canopies. The replicated studies provided additional opportunities to evaluate sampling techniques, drift and environmental fate; to validate the FSCBG aerial spray dispersion model;. and to compare biological response to dose deposition. Orchards, with their relative uniformity of canopy structure and density, are ideal for conduct of such studies. John W. Barry, USDA Forest Service, designed and conducted the studies, and Milton E. Teske and Alina Z. MacNichol, Continuum Dynamics, Inc., performed the data analyses. The results are reported in a three-part report series as follows:

1. <u>Canopy Penetration in Almond Orchards</u>

   Part 1:

   Efficiency of Deposition within the Canopy
   USDA/FPM Report 96-3

2. <u>Canopy Penetration in Almond Orchards</u>

   Part 2:

   FSCBG Simulation of Drop Deposition and Downwind Drift
   USDA/FHTET Report 96-03

3. <u>Canopy Penetration in Almond Orchards</u>

   Part 3:

   Biological Response within the Canopy
   USDA/FHTET Report 96-04

The 1994 study was made possible by the outstanding cooperation of Bob Hennigan, Frank Zalom, Gary Kirfman, Joe Connell, Harold Thistle, and Pat Skyler; and similarly the 1985 study was made possible by Bob Hennigan, Bruce Grim, Jim Keetch, and Bob Ekblad.

J.W. Barry
Davis, CA
November 17, 1995

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Executive Summary

This paper examines the efficacy of different forms of treatment in controlling peach twig borer in a broadleaf (almond) canopy. For each stage of flower and foliage, a formulation of *Bacillus thuringiensis* (Bt) was applied aerially in three phases. Each phase represented a different type of application (different spray volume, Bt concentration, and atomization) and was conducted over specific portions of the orchard. The number of peach twig borer larvae surviving each of the Bt treatment phases at two different stages of tree foliage were recorded using two methods: by counting the number of live pupae on cardboard bands around sample trees, and by counting the number of shoot strikes made by live insects on replanted trees. Predator spiders were also found in the sample tree bands.

Results from predator spiders, peach twig borer pupae, and shoot strike counts are normalized by data from "untreated" (control) areas to determine insect survivability after each type of Bt treatment. Both sets of peach twig borer data (pupae and shoot strikes) are in good agreement, and dose-response plots are generated showing the survivability of peach twig borer at different application rates of NOVO Biobit XL (Bt). As expected, the larger the application rate of the biopesticide, the higher the insect mortality achieved.

Response of the peach twig borer to Bt application during the 1994 Hennigan Orchard field trials provides an excellent opportunity to evaluate the dose-response of a target species in a broadleaf canopy at different stages of flower and foliage development.

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1. Introduction

The main objectives of the field trials conducted at Hennigan Almond Orchard, Chico, CA, in January, February and March of 1994 were to determine the efficacy of different forms of treatment in controlling peach twig borer, an insect pest which injures almond trees and reduces crop yield, and to evaluate the feasibility of reduced volumes and biological sprays. Before the advent of synthetic organic pesticides, the peach twig borer was considered to be the most important insect pest of almonds. Its feeding results in direct damage to the nuts: if left untreated, an infested tree can lose over 30% of its almonds in a growing season (Zalom et al., 1994b).

Peach twig borer has typically been managed with a dormant season application of an oil and an organophosphate insecticide (Zalom et al., 1994b), but such treatment has recently been implicated in poisoning of the red tailed hawk, and in contamination runoff into waterways. While pest control has been achieved with these dormant sprays, survival of a sensitive species (in this case, the red tailed hawk) may have been compromised. Thus, the use of organophosphate insecticides may be severely limited by regulatory agencies, and alternate methods of controlling peach twig borer must be explored.

The 1994 Hennigan Orchard trials evaluated three spray regimes of application of *Bacillus thuringiensis* (Bt) to control peach twig borer. Recommended control using Bt requires two applications at bloom time, one at the popcorn (or bloom expansion) stage and the other at blossom petal fall stage. Although ground application could be considered, since the timing of the applications is critical to successful control of the pest, aerial application would have to be used for large orchards, or in conditions unfavorable to ground spraying (such as wet ground).

The Hennigan trials were conducted in an almond orchard, over three stages of foliage: dormant stage (January); popcorn stage (late February); and blossom petal fall stage (early March). The orchard was divided into twenty treatment plots, four of which were untreated control plots. During the dormant stage, a conventional chemical treatment was applied to four of the plots. At the other two stages of foliage, three treatments of Bt (with different tank mixes and spray systems) were aerially applied, each to four other plots. Parts 1 and 2 of this study examine the spray deposit data available from the February and March treatments. Part 1 (MacNichol, 1996a) assesses deposition effectiveness within the orchard canopy during each type of treatment and for each stage of flower and foliage; the overall effectiveness is represented by Relative Index (RI). Part 2 (MacNichol, 1996b) compares FSCBG (Forest Service Cramer-Barry-Grim, Teske et al., 1993) predictions with data within the canopy during each treatment phase, as well as with downwind drift data.

In this report (Part 3), biological response data from the Hennigan trials are evaluated. Biological assessment of the peach twig borer was conducted after the blossom petal fall treatment by counting the number of predator spiders, surviving peach twig borer pupae, and shoot strikes on designated trees, and is further described in the next section.

2. Field Trials Summary

The Hennigan Orchard trials conducted in early 1994 are described in detail in Zalom et al. (1994b), as well as MacNichol (1996b). The trials were conducted at Hennigan Almond Orchard from January to March, 1994. Biological data, which are the subject of this report, were collected in early April, nearly one month after the last aerial treatment with the biopesticide Bt.

The scope of the field trials is summarized in Table 1. Phases B and C represented low volume and high volume Bt treatments, respectively, applied with a helicopter and CP hydraulic nozzles; Phase D represented ultra low volume (ULV) Bt treatments applied with a fixed-wing airplane and Micronair rotary atomizers. The spray material used was NOVO Biobit XL (Foray 48B), an insecticide that uses Bt as its active ingredient.

Figure 1 shows the layout of the orchard during the trials, and location of the four untreated control plots. Four plots (replicates) were treated during the dormant season, in January, with the conventional chemical treatment. The remaining plots were aerially sprayed with Bt during the two days of bloom time testing, February 22 and March 8. There were five sample trees in the center of each plot, on a north/south line. Each sample tree contained four beverage can samplers for data collection on the days of treatment (MacNichol, 1996b). Sample trees were also scaffolded, and the scaffolds were encircled with cardboard bands stapled to the trunk. Biological data consisting of peach twig borer pupae and predator spiders were collected from these bands. Figure 2 shows the position of the scaffolded trees in a typical sample plot.

After the popcorn spraying (on February 22), the sample trees in each plot assigned to Phases B, C and D were scaffolded and banded. Sample trees in the plots assigned to untreated control areas were also scaffolded and banded. Thus, cardboard bands were in place in areas treated with Bt, as well as in untreated control areas, before the blossom petal fall spray treatment (on March 8). During the ensuing month, larvae on the trees crawled down the scaffold to find secluded places for pupation; Zalom et al. (1994b) believed that the larvae would pupate in the cardboard bands. The bands were removed in early April, before the emergence of adult insects, and were returned to the laboratory (at the University of California, Davis), where they were dissected to remove and count the relative number of pupae remaining in treated and untreated plots. Predator spiders were also found in the bands.

A second method of assessing insect population was to count the number of shoot strikes in early April that resulted from live insects feeding on the trees. Overwintering larvae that emerged from their hibernacula in early April attacked tree shoots; these live insects apparently survived the repeated spraying of Bt, and their damage to twigs gives an alternate measure of the effectiveness (or, rather, the lack of effectiveness) of the spray treatments. Shoot strikes per tree were assessed visually on the smaller replanted trees in the center of each of the plots. Zalom et al. (1994b) stated that replant trees were used for this purpose because their shoot growth was more vigorous than growth on older trees, allowing for easier and more accurate determination of the number of shoot strikes. The exact positions of replant trees are not given; however, they were on the tree sampling rows or adjacent to them.

Following dissection of the cardboard bands, the number of peach twig borer pupae from all cardboard scaffold bands on a single tree were pooled to determine the total number of pupae in each tree. The average number of pupae in each treatment plot were then calculated. These numbers indicate the survival of pupae following treatment. The number of shoot strikes observed on each tree were also averaged by treatment plot. Since shoots were attacked by adult insects which had survived both Bt treatments, shoot strike data also indicate insect survival. Predator spiders were counted in this way as well.

Predator spider data are provided by private communication from F.G. Zalom, University of California, Davis (1995). Although Zalom et al. (1994b) indicate that adult peach twig borer emergence was also determined using pheromone traps in the orchard, no biological data other than counts of predator spiders per band, peach twig borer pupae per band and counts of shoot strikes have been provided. Table 2 summarizes the biological field data available for the 1994 Hennigan trials (F. Zalom, private communication, 1995 and J.W. Barry, private communication, 1995). The column on the right normalizes all entries in each set by the untreated value, to recover a relative effect of the treatment phase.

Table 1: Scope of the 1994 Hennigan Trials

Plot	Acres	Phase	Aircraft/Nozzle Type	Nozzles	Tank Mix[1]	Applic. Rate
1	10.9	A	Bell 206 / CP	64	Supracide	20.0 gal/acre[2]
2	8.1	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
3	8.1	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
4	108.0	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
5	16.3	B	Bell 206 / CP	20	Bt (14.6 BIU)[3]	5.0 gal/acre
6	10.9	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
7	8.1	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
8	8.1	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
9	16.3	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
10	10.9	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
11	8.1	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
12	8.1	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
13	8.1	UNTREATED Control				
14	10.9	UNTREATED Control				
15	8.1	UNTREATED Control				
16	8.1	UNTREATED Control				
17	16.3	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
18	10.9	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
19	8.1	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
20	8.1	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre

1. The tank mix for Phases B, C, and D consisted of undiluted Bt with Blue #5601, Grape #5758, and Rhodamine WT liquid dyes, respectively, and water (Phase D was undiluted).

2. Phase A was a conventional chemical treatment applied in January, 1994 during tree dormancy. The tank mix for this treatment consisted of 6 lbs. Supracide, 2 gal. oil, 7% zinc, water and Rhodamine liquid dye. Data from Phase A are not considered in this report.

3. Bt was NOVO Biobit XL.

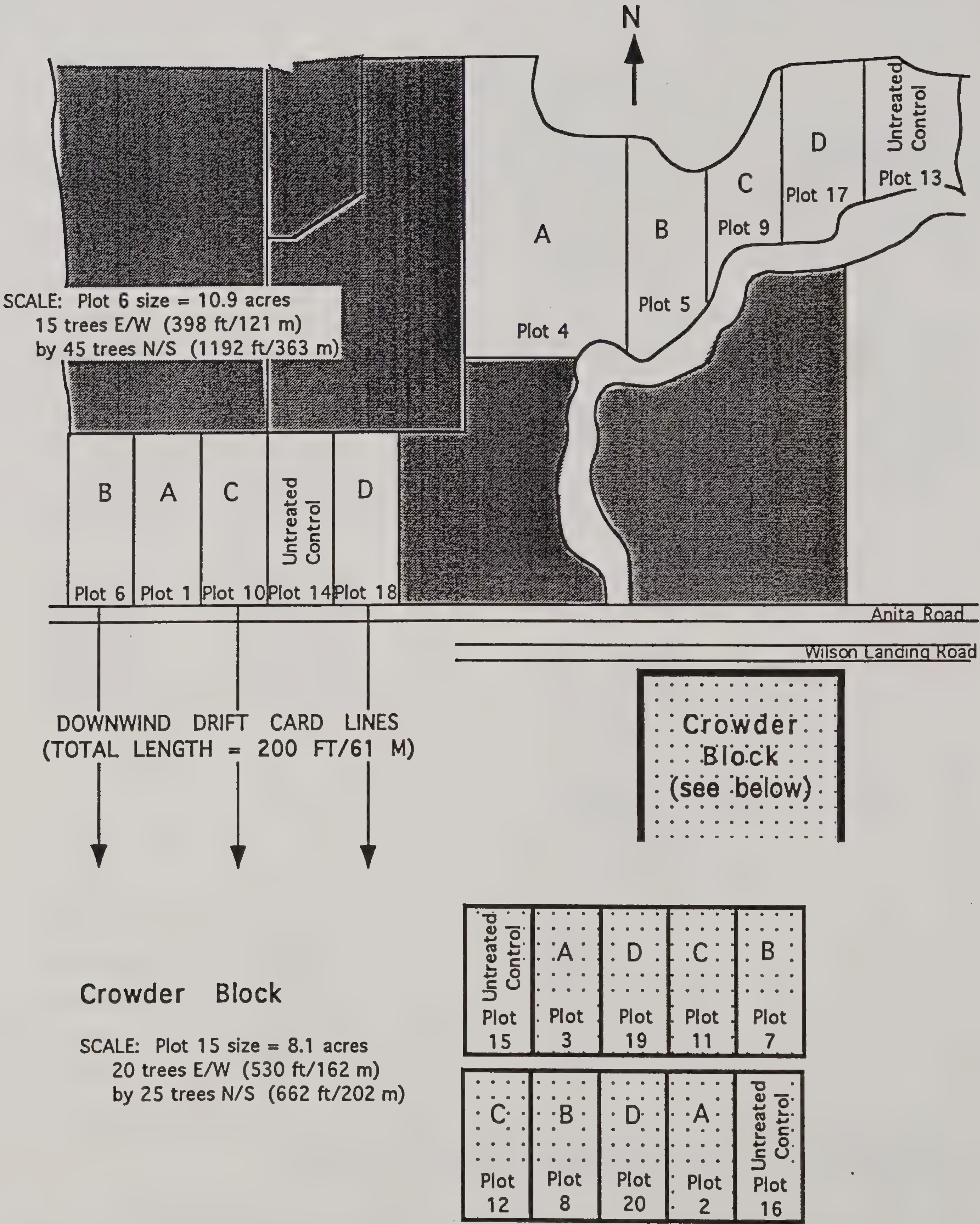
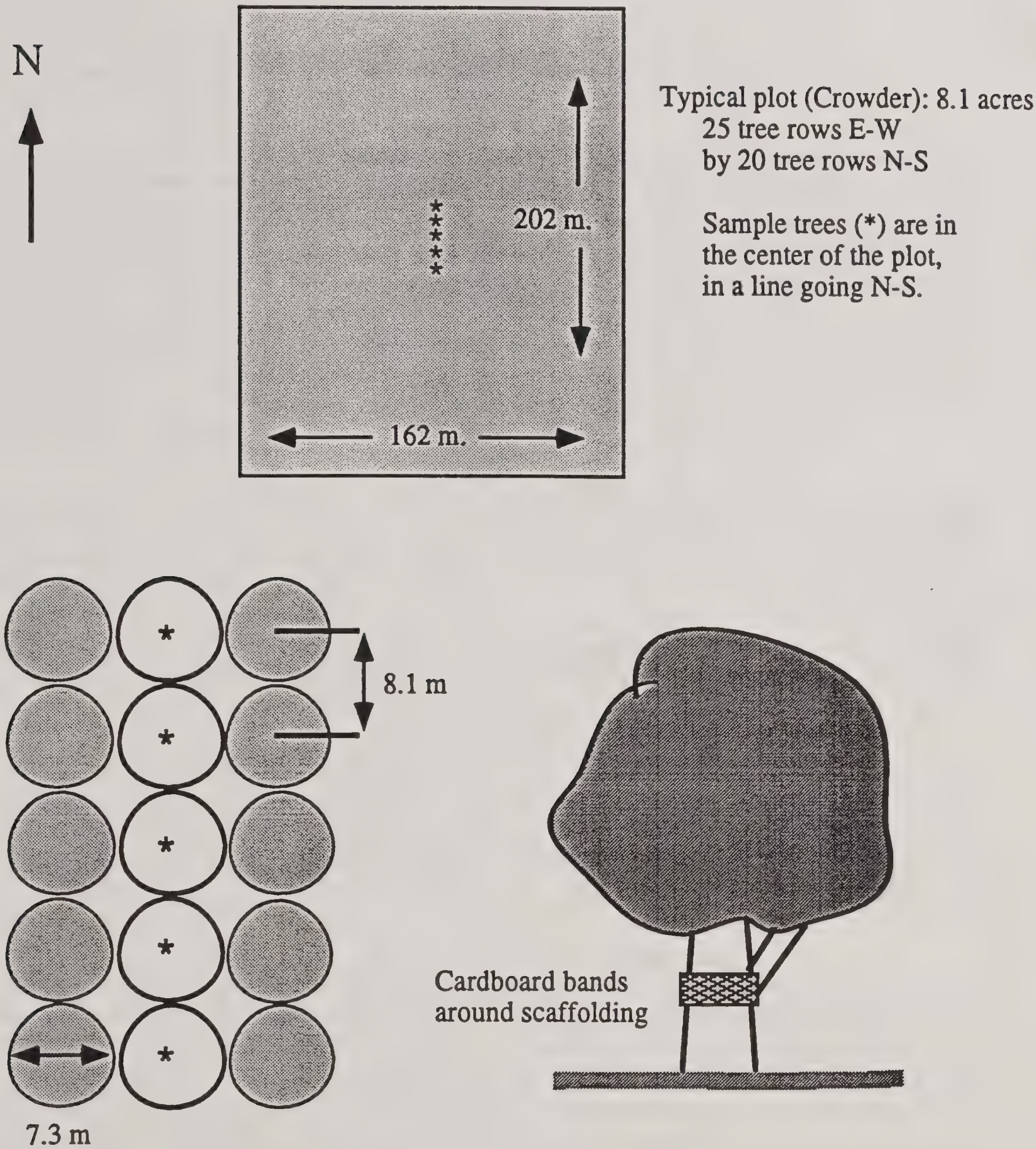


Figure 1: Schematic of Hennigan Almond Orchard (Chico, CA) showing plot layout for the 1994 trials. Shaded areas of the orchard were not used during the trials.



Hennigan Almond Orchard, 1994:

- trees are 8.1 m. center-to center
- mean canopy height = 7.6 m.
- 5 sample trees in the center of each plot
- after popcorn stage treatment, each sample tree was scaffolded and wrapped with cardboard bands for collection of biological data

Figure 2: Placement of sample trees with scaffolding in Hennigan Almond Orchard for the 1994 trials

Table 2: Summary of Biological Data Available for the 1994 Hennigan Trials

PREDATOR SPIDERS

Phase	Mean Number of Spiders per Tree Band	Normalized
A	0.49	1.09
B	0.31	0.69
C	0.77	1.71
Untreated	0.45	1.0
D	0.62	1.38

PEACH TWIG BORER PUPAE

Phase	Peach Twig Borer Pupae per Tree Band	Normalized
A	0.45	0.38
B	0.35	0.29
C	0.52	0.43
Untreated	1.20	1.0
D	0.88	0.73

SHOOT STRIKES

Phase	Shoot Strikes per tree	Normalized
A	0.70	0.15
B	2.14	0.47
C	1.99	0.44
Untreated	4.57	1.0
D	3.67	0.80

3. Evaluation of Biological Field Data

As mentioned in the introduction to this paper, the survival of sensitive species in or near the spray area is of increasing concern to growers and pesticide applicators as well as environmentalists. Non-target and sensitive species may include animals (such as fish and raptors), desirable insects (such as Lepidoptera), and vegetation. Overspraying an area with pesticide, or spraying in conditions which allow for significant drift, can severely compromise the survival of a sensitive species. In addition to ensuring the immediate survival of such species, it is important to protect sensitive areas such as ponds and breeding grounds, which affect the long-term survival of many species of animals, insects and plant life. Runoff into waterways is of additional concern because contaminated water can also affect human health.

Thus, the current strategy for most aerial applicators is to control the population of the pest with an amount of chemical or biopesticide which will minimize crop or tree damage without compromising the survival of any desirable species. This is a difficult strategy to put into effect, not only because of the many variables inherent in the spraying of pesticides (maintaining the desired flight path, altitude and amount of spray dissemination), but also because the meteorological conditions over a spray area can vary over even a short span of time. In-swath deposition is particularly affected by accurate GPS tracking, uniform swath width (or lane separation), and crosswind.

A further complication involves determination of the optimum level of pesticide to be sprayed. There are two issues of concern: defining the maximum level of pesticide which can be sprayed without compromising survival of the non-target species; and, defining the level of pesticide which results in effective population control of the target species. Both of these levels must be known for effective, economical and safe aerial spraying to be achieved.

The most common way to look at the issues of insect mortality and survival of sensitive species is by means of a dose-response curve. The response of a species (either a desirable species or a pest), in terms of index of growth or percent mortality, is shown as a function of pesticide dosage. In order to construct such a curve with the field data summarized in Table 2, we must first normalize the results for each set of data (predatory spiders, peach twig borer, and shoot strikes) by the "untreated" entry in each set, since without additional information we would have to assume that the untreated plots enable survival of the insect.

It is clear from Table 2 that the predatory spider data is not consistent, since all other treatment phases except Phase B recover more spiders than in the untreated plots. The peach twig borer pupae and the shoot strikes are, however, quite consistent. A dose-response plot of both of these sets of data (versus application rate from Table 1) is shown in Figure 3. Here it may be seen that, although there is some scatter in the data, the peach twig borer pupae and shoot strikes by peach twig borers both adequately represent the survivability of the insect.

For comparison, we may examine dose-response data from the recent Utah 1993 study (Teske, 1995a and Zalom et al., 1994a), as summarized in Table 3 and plotted in

Figure 4. Here "CFU" refers to colony forming units of the Bt spore. There is a greater amount of scatter here (the sites were down canyon from the edge of the spray block to 3 kilometers), but the trend is still evident. As more material is deposited, the target insect is more strongly affected, until survivability reduces to zero (as in Figure 3), or, alternately, mortality approaches unity (as in Figure 4).

The dose-response curves generated in Figures 3 and 4 indicate, as expected, that the larger the application rate or deposition on foliage, the higher the insect mortality achieved. Such curves, however, must be used with corresponding dose-response curves for non-target (sensitive) species to complete the spraying picture. Minimizing damage to non-target species can be achieved by off-setting the aircraft flight lines away from the spray block boundaries by means of a buffer zone. The buffer zone is that distance downwind of the aircraft flight path over which the concentration of pesticide deposited is damaging to the sensitive species: within the buffer zone, desirable species can be at risk.

Without a companion curve to show the mortality rate of sensitive species as a function of application rate or deposition on foliage, it is not possible to determine an optimum application rate of the biopesticide. Without mortality data for the sensitive species, the width of the buffer zone for a selected application rate is not known.

Another recent study attempted to quantify the levels of insecticide for effective population control of a pest. MacNichol and Teske (1995) examined insect mortality data from the USDA Forest Service/US Army C-47 MISS trials. Mortality rate of spruce budworm larvae and effective swath width (that swath width for which there was 100% insect mortality within 24 hours of spray application) were evaluated. At the dosage of Zectran sprayed (150 gal/min at 0.5 gallons of Zectran in 2 gallons of spray per acre), an average mortality rate of 46% was observed over the entire test grid.

It is interesting to note that the effective swath width, as defined by MacNichol and Teske (1995), is a companion to the buffer zone described above. While a buffer zone indicates an area of buffering location of non-target species mortality, the effective swath width indicates an area of 100% mortality of the target species. Effective swath width and buffer zone are thus seen to be tied together with dose-response curves (as illustrated in Figures 3 and 4) for target (effective swath width) and non-target (buffer zone) insects. By including dose-response information in FSCBG (Teske, 1995b), productivity and cost benefit may be modeled. This is the current direction in extending aerial spray models for use by managers in planning pesticide applications (Richardson 1995).

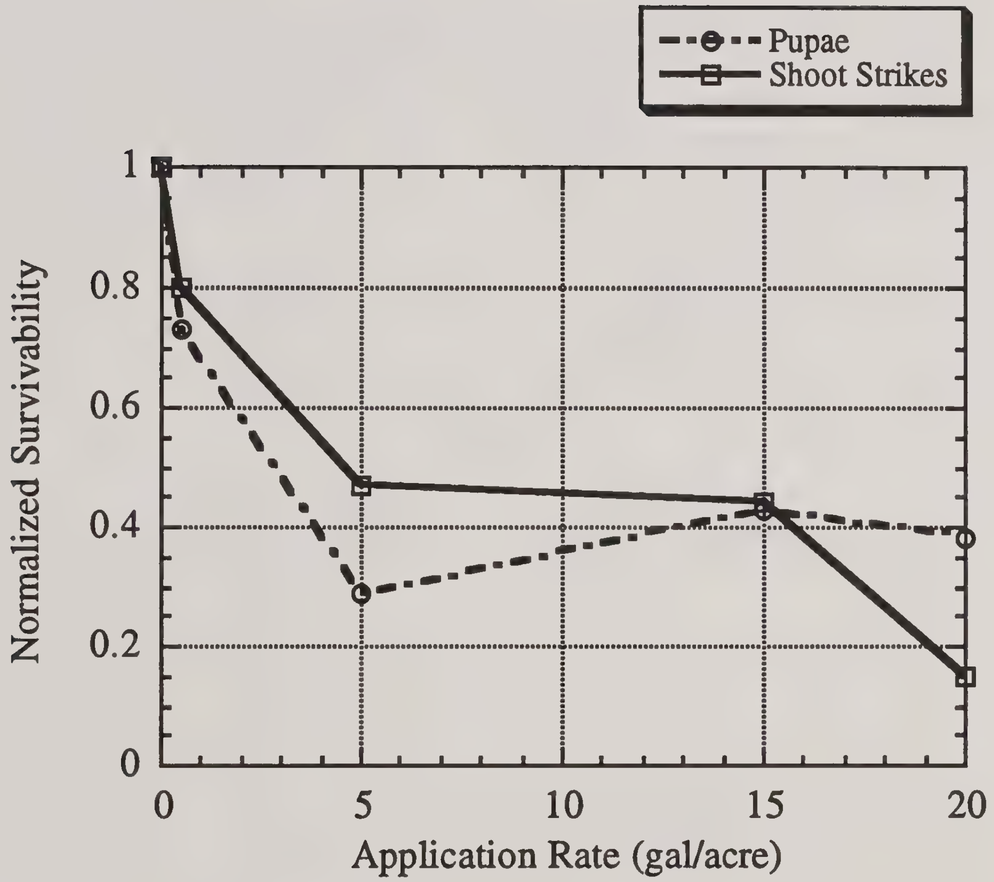


Figure 3: Dose-response curve for peach twig borer based on field test data from Hennigan Orchard. The dashed line shows dose-response as calculated from surviving pupae; the solid line shows dose-response as calculated from shoot strikes. At normalized survivability of 1, all peach twig borer insects survive; at normalized survivability of 0, none survive.

Table 3: Summary of Biological Data for the 1993 Utah Study

Deposition Level (CFU/mm^2 of foliage)	Normalized Mortality of Lepidoptera[1]
0 (Control)	0.0
354	0.79
710	0.84
4342	0.67

Deposition Level (CFU/mm^2 of foliage)	Normalized Mortality of Lepidoptera[2]
0 (Control)	0.08
87	0.10
364	0.40
445	0.20
1045	0.24
6478	1.0

1. Mortality data from *Calloprys Sheridani*

2. Mortality data from *Incisalia fotis*

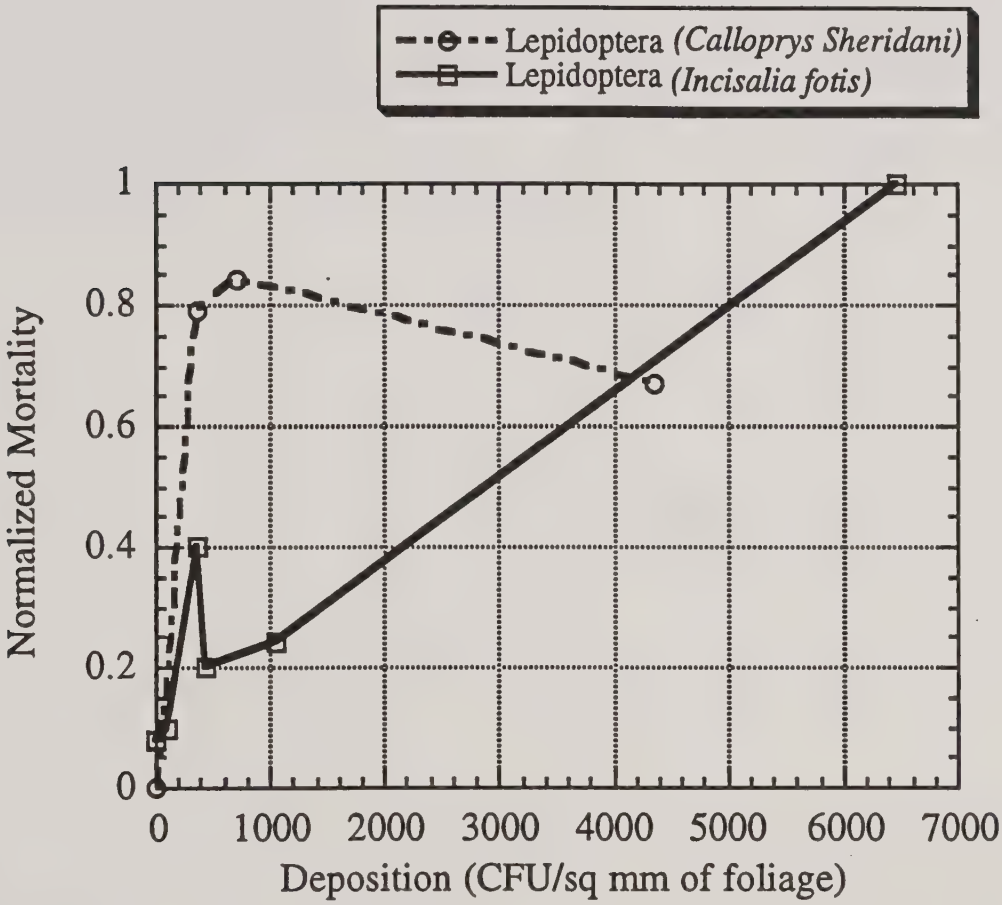


Figure 4: Dose-response curve for Lepidoptera based on field test data from the 1993 Utah Study (CFU are colony forming units). Data shown are averages of three tree treatments. The dashed line shows dose-response to Bt as calculated for *Calloprys Sheridani* ; the solid line shows dose-response as calculated for *Incisalia fotis*. At normalized mortality of 0, all of the Lepidoptera survive; at normalized mortality of 1, none survive.

4. Summary

Response of the peach twig borer to the biological insecticide Bt from the Hennigan field trials presented in this report provides an excellent opportunity to evaluate dose-response in a broadleaf canopy at different stages of flower and foliage development. The number of peach twig borer larvae surviving each of three Bt treatment phases at two different stages of tree foliage were recorded using two methods: by counting the number of live pupae on cardboard bands around sample trees, and by counting the number of shoot strikes made by live insects on replanted trees. Insect mortality data generated by each method are in good agreement, and dose-response curves for the peach twig borer as treated with NOVO Biobit XL (Bt) can be generated.

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